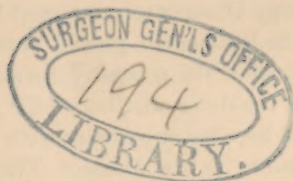


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ON THE PERFORMANCE OF A NEW FORM OF LEVEL INVENTED BY
MR. JOHN CLARK OF THE U. S. COAST SURVEY. By WILLIAM
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[ABSTRACT.]

EXPERIENCED observers have often expressed the opinion that the level as ordinarily constructed cannot be regarded as an instrument of precision. It will be admitted on every hand that it is not made by a scientific method. In fact, the method of construction is of the most crude kind. The maker chooses a glass cylinder as uniform in thickness and density as he can obtain and proceeds to grind an interior curve of unknown radius with an emery and a polishing tool. He has no means of determining the exact radius by observation. He is unable to test the equality of the curvature on each side of the centre, until after the cylinder has been filled with a fluid and after the ends have been hermetically sealed. Even then the test is only a relative one. It is of the

same kind as the observations which are made with the completed level.

As the result of many years of experience I have reached the conclusion that an astronomical level can be regarded as an instrument of precision, only when it is subjected to adequate tests during the series of observations in which it is employed. A given level may measure small angles with great precision, but the same level under different conditions may give untrustworthy results.

Even with an instrument which has no graduated circle, an adequate level trier can be constructed by placing a graduated scale at a known focal distance. In the case of the Meridian Circle of Harvard College Observatory the level is placed in Y's attached to the cube of the instrument placed parallel with the optical axis.

In order to show the necessity for repeated and continuous observations for the determination of the value of one division of the level, I record here my experience with the companion level of the instrument known as the Russian Transit. It was made in the workshop of the Pulkowa Observatory.

I began the observations about eight o'clock in the morning of Nov. 13, by comparing the readings of the circle with bubble first at the middle of the tube and then at the extreme end. Proceeding in this way with each five divisions in succession I was surprised to find, not only a continued diminution of the value of one division, but a well defined shifting of the zero of the level. By noon I had nearly completed the examination for the first half of the divisions. I then opened the shutters for an observation of the sun. After an interval of ten minutes, observations with the level were resumed when it was found that the value of one division, determined from the same space as before, had increased by one-fourth of its mean value. It will be sufficient to give in illustration the results of the observations on three days.

	1881 Nov. 13.	Nov. 14.	Nov. 15.
Shutters closed.	1 div = 1.76'' Th. = 38°	1 div = 1.20'' Th. = 40°	1 div = 2.06'' Th = 47°
Shutters open.	1 div = 2.08 Th. = 65°	1 div = 2.06'' Th. = 70°	1 div = 1.78'' Th = 36°

In these observations the level was held in position in the Y's with a light spring. A second series of observations was made with the tube mounted as follows: At the suggestion of Mr. George B. Clark, oval rings of brass were fitted loosely upon the tube and held in position with wax. These rings were then placed in

Y's one end being fastened with a spring clip while the other end was free. A third series was made with the tube fastened directly to the cube of the telescope at its neutral points by means of a hard cement. The results are given below.

SERIES I.	SERIES II.	SERIES III.
1881 May 22 1 div = 2.90''	1881 Nov. 23 1 div = 1.63''	1881 Oct. 7 1 div = 2.25''
" 22 = 2.68		" 7 = 2.25
Sept. 1 = 2.60	" 25 = 2.48	" 8 = 1.64
" 7 = 1.83		" 8 = 1.62
" 7 = 1.92	" 29 = 2.18	" 8 = 1.65
" 8 = 2.83		" 9 = 1.62
" 9 = 2.74	1882 Jan. 8 = 1.80	" 9 = 1.59
" 12 = 3.42		" 12 = 1.71
" 13 = 2.89	" 12 = 1.94	" 13 = 0.83
		" 13 = 1.28
		" 13 = 1.17
		" 20 = 1.23
Mean 2.65	Mean 2.01	Mean 1.57

It is hardly necessary to say that this level has been discarded as worthless. On the other hand the mounted level furnished with the Russian Transit proves to be an excellent one.

A similar test with a level invented by Mr. John Clark has given good results. The level tube is supported upon centres which are attached to a plate which revolves freely upon another plate described by the inventor as a "reference plate." This "reference plate" is attached to the cube of the telescope by three adjusting screws. The following are the steps of an observation.

The telescope pointing north, the bubble is read for position east and position west. The telescope pointing south, the level is now on the under side of the cube. Revolving the tube upon its centres 180° , the bubble is read as before. This level therefore gives not only the inclination of the axis, but the ellipticity of the pivots.

This form of level is especially adapted to the easy determination of the value of one division. I give below the results of the determinations thus far made. The separate results are the re-

sults of observations on different days. They therefore involve the accidental errors of observation.

												Means.
1881.	Sept.	2.78''	2.71''	2.79''	2.80''	2.96''	2.87''	2.87''	3.07''	2.63''		2.83''
	Oct.	2.61	2.99	2.79	2.53							2.73
	Nov.	2.82	2.88	3.11	3.46	2.85	2.84	2.91	2.95	2.69	2.71	2.74
	Dec.	2.85	2.96	3.13								2.98
1882.	Feb.	3.21	2.97	2.69	2.77	2.99	2.62					2.87
	Mar.	2.73	3.21									2.97
	Apr.	2.92	2.80	3.01								2.91
	May	2.85	2.93									2.89
	June	2.87	3.01									2.94

The steadiness of the level of the instrument is something remarkable as is shown by the following separate observations which are here published by the permission of Professor Pickering the Director of the Observatory.

1882 Feb.	3	$b = +.78^s$	Apr.	3	$b = +.77^s$	June	25	$b = +.74^s$
"	5	$b = +.81$	"	14	$b = +.80$	July	3	$b = +.63$
"	14	$b = +.82$	"	24	$b = +.81$	"	10	$b = +.72$
"	23	$b = +.80$	May	1	$b = +.79$	"	31	$b = +.61$
"	26	$b = +.80$	"	15	$b = +.75$	Aug.	16	$b = +.71$
Mar.	5	$b = +.78$	"	29	$b = +.72$	"	25	$b = +.68$
"	14	$b = +.73$	June	11	$b = +.61$	Sept.	7	$b = +.66$
"	20	$b = +.74$	"	19	$b = +.66$	"	25	$b = +.61$
						Oct.	2	$b = +.65$

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